Technical Note

Using Gun Blue to Enhance Fingermark Ridge Detail on Ballistic Brass

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Abstract: Brass cartridge cases are the most common type of cartridge case found at crime scenes, but it is not always feasible to obtain identifiable fingermarks on these cartridges. This study evaluates the effectiveness of gun blue as an enhancement method on fingermarks that were deposited on brass metal discs and left to age (2, 7, 14, and 30 days) under different environmental conditions, namely, under dark conditions, under ambient light, and outdoors. Ten different donors (5 males, 5 females) were employed for this study, and their fingermarks (60 per donor) were enhanced with gun blue solution (50% v/v). It was possible to enhance aged fingermarks (natural and groomed) that had been deposited on the brass metal discs to an identifiable level, with the fingermarks left outdoors being the most challenging to enhance. The feasibility of enhancing fingermarks on fired brass cartridges shot from different firearms was also assessed. Despite favorable results being achieved on fired brass cartridge cases, more research is required to assess whether reliable enhancement can be achieved on fired cartridge cases under real crime scene conditions.

Introduction

When someone touches a surface, friction ridge detail may be deposited on this surface. This fingermark ridge detail frequently requires enhancement to be visualized. Because of the rise of firearm offenses in the United Kingdom and the low recovery rate of fingermarks[1] from ammunition, some

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research groups [2, 3] have tried to develop a better protocol of fingermark recovery from ammunition. In a paper by Girelli et al.[3], it was demonstrated that using gun blue as a single enhancement method can lead to the recovery of Level 2 detail on fired cartridge cases (although the recovery rates were less than ideal). Morrissey et al. [4] demonstrated that fingermarks of sufficient quality for identification purposes can be obtained even on fired cartridge cases; however, only one donor (female) was employed in their experiments.

Most of the commercial gun blue reagents contain selenious acid, cupric salt, and nitric acid. They may also contain phosphoric acid, zinc, and ammonium salt. Gun blue is a reagent that is used for the patination of metallic surfaces (Equation 1), which helps to protect the surface from scratches and oxidation.

$$H_2SeO_3 + 4H^+ + 4e^- \rightarrow Se + 3H_2O \qquad \text{Equation 1 [4]}$$

However, when a greasy, waxy, or oily component is present on a metallic surface, the application of gun blue does not stain this area. It is suspected that the aforementioned components act as a protective layer, not allowing gun blue to react with the metallic surface that lies beneath. This phenomenon is the reason why latent fingermarks (which may contain greasy, waxy, and oily components) can be developed when using gun blue. The majority of previous studies used gun blue as a part of sequential treatments and reported unsatisfactory fingermark development when gun blue was used independently [5–7]. It is noteworthy that the studies mentioned earlier report that the protocols they used were not standardized, and that may have hindered fingermark development.

The aim of this study was to determine whether gun blue can be used as a stand-alone development technique to enhance fingermarks that had been left to age under various environmental conditions on a ballistic brass surface. In this study, the number of donors is extended and an attempt to standardize the development protocol is discussed. Differences in male and female donors are examined, because contradictory studies have been published regarding the differences (or similarities) in compounds (or compound ratios) in fingermarks from male and female donors [8–11]. A successful development technique using gun blue would provide an efficient, cost-effective methodology with excellent sample throughput.

Materials and Methods

Ballistic Brass Metal Discs

Experiment 1

Ballistic brass metal discs (custom order, 3x3 cm, natural finish, Metal Sheets Inc., Liverpool, U.K.) were chosen for the initial experiment. Their elemental analysis revealed that they can be regarded as equivalent to brass cartridge cases (65% Cu, 35% Zn). The discs were washed with warm water and detergent (Decon 90 5%v/v), rinsed with ethanol, and left to dry in the open air. Ten donors[1] were used for this study (5 males and 5 females of different ethnicities and of a median of 28 years) to assess the reliability of the method. The donors rubbed their hands on their foreheads and clenched their hands prior to depositing one ("groomed") fingermark from their right thumb on each disc. The donors applied light pressure on the surface for 3 seconds. Each donor deposited 60 fingermarks (1 fingermark per disc, not a depletion series). From the total of 600 fingermarks, three equally numbered (n = 200) groups were created. One group was kept constantly under dark conditions in cardboard containers; one group was kept in ambient light; and one group was exposed to outdoor conditions (average monthly temperature was 8 °C with 13 days of average 37 mm rainfall). The three groups were further divided into subgroups, which were tested at 2, 7, 14, and 30 days. As a point of reference, fingermarks developed directly after deposition were obtained from all of the donors (5 fingermarks per donor).

Experiment 2

Additionally, eight of the donors were used in another experiment to assess gun blue's enhancing ability when dealing with natural fingermarks. The donors washed their hands with soap and water 30 minutes prior to depositing the print, and then resumed their normal daily routine [12]. This protocol was followed in order to get a type of print that would resemble the ones found at crime scenes. Each donor deposited 1 fingermark onto 12 separate discs. The fingermarks were then divided into 6 groups of 16. One group of fingermarks was tested immediately (fresh), another after 7 days, and another after 14 days. The storage times were chosen based on what the fingermark literature suggests and the duration of the project [12, 13]. The

[1] This study received ethical approval from the Liverpool John Moores University ethics committee.

other three groups of fingermarks were subject to being stored in the dark, under ambient light, and outside, each for 7 days before the application of gun blue. The final two groups of the natural fingermarks were also subject to alternating ambient light and dark conditions (12 hours each) in order to simulate crime scene conditions.

Fired Cartridge Cases

In order to evaluate gun blue's effectiveness in enhancing fingermarks on fired cartridge cases, three experiments were performed. Because of the United Kingdom's legislation regarding firearms and ammunition, it was not possible to conduct all experiments on the same day; the completion of experiments was subject to the availability of the ammunition, the shooters, and the donors.

Experiment 1

In the first experiment, one male donor deposited groomed fingermarks (the same type of fingermarks as in the initial experiment) on 20 cartridges (7.62 mm Bisley Target -1 per case) that had been previously cleaned using the same protocol as for the brass discs. The cartridges were discharged using a single shot bolt-action rifle. The fired cartridges were processed the following day (approximately 12 to 16 hours after firing).

Experiment 2

In the second experiment, 2 male donors deposited 6 groomed fingermarks each, 1 on each cartridge (Winchester .45 ACP) (a total of 12 fingermarks) and they were discharged using a .45 Glock pistol. The fired cartridges were processed the following day.

Experiment 3

In the third experiment, 4 donors (2 males and 2 females) deposited a mix of natural and groomed fingermarks on a total of 20 cartridges (Winchester .38 Special, J.S.P.), which were discharged with a .38 Smith & Wesson revolver 5 days after the fingermarks had been deposited. These cartridges were then processed within 2 hours after firing.

Gun Blue Protocol

The gun blue solution consisted of 50% Birchwood Casey Perma Blue solution and 50% distilled water. Each metal disc was immersed into the gun blue solution and was held by using tweezers. The timer was started upon the whole contact of the metal disc with the solution. The discs were constantly observed. When ridge detail of sufficient quality was visible, the metal disc was removed from the solution and placed into a beaker of distilled water for a few seconds to halt the reaction. The immersion times were recorded.

Ridge Detail Evaluation

The developed ridge detail was examined and given a grade as described in Table 1.

Grade	Criteria
3	Pattern or ridge flow is disclosed with clear characteristics throughout. Identifiable ridge detail.
2	Pattern or ridge flow is disclosed; however, characteristics are not clear throughout the whole impression. May possibly be used for identification purposes.
1	No clear pattern or ridge flow, with few or no characteristics disclosed. Cannot be used for identification purposes.
0	No ridge detail developed.

Table 1

Outline of the grading scheme used for assessment of enhanced fingermarks; adapted from Hartzell-Baguley et al. [10]

Photographs of all impressions were taken with a NIKON D750; camera mode: manual; shutter speed: 1/250; aperture: wide open (f/1.4); ISO: 3200; white balance: Auto WB; autofocus: AI-Servo; drive mode: continuous; metering: N/A; image quality: raw). Grading was done by examining the fingermarks on the cartridges and the discs in the photographs, using a magnifying fingerprint glass. Independent grading was also conducted by a second examiner. Any differences in grades on certain fingermarks were later discussed and agreed upon.

Statistical analysis of the grades assigned on fingermarks was performed in Excel, using the chi-square test of independence after converting the grades from numbers to nominal data (either identifiable or nonidentifiable).

Results and Discussion

Processing Time

Morrissey et al. [4] reported that the average processing time was 32 seconds. In the work reported herein, which included a larger sample and a variety of donors, the processing times differed (from 20 to 120 seconds), depending on the time interval between the deposition of the fingermark and processing (Figures 1a-1f). The fingermarks that were deposited were groomed fingermarks, which means that their content in fatty components was higher than in other types of fingermarks [13], making them the best candidate for an enhancement method such as gun bluing. Any time differences that may have occurred could have been due to inter-donor and intra-donor variability (most likely because of the different amount of sebaceous material contained in each fingermark), different age, and storage conditions of the fingermark samples [12,13].

In some of the aged samples (Figures 1a, 1c) that had been left under dark and ambient light (especially for those that had been left for 2 days), the processing time actually dropped with age, which may indicate a reduced water content and better "protection" of the substrate with the remaining oily or greasy components [14].

Generally, fingermarks on the brass discs that were kept under dark conditions were enhanced faster than the ones that were left under ambient light and outdoors. The brass discs that were left outdoors required the longest processing time (Figures 1e, 1f) and produced unexceptional results, which seems logical because of their exposure to environmental conditions (rain, wind) that may have removed or altered a lot of the fingermark residue that had been initially deposited on the discs. This would allow greater exposure of the brass substrate for reaction with the GB, thus producing poorer fingermark development.

The fingermarks that were left under dark conditions did not show a clear trend of an increasing processing time as they aged. On the contrary, increased processing times were observed on aged fingermarks that were left under ambient light and outdoors. Dark conditions appear to decelerate the degradation process of the more oily substances in fingermarks [15].

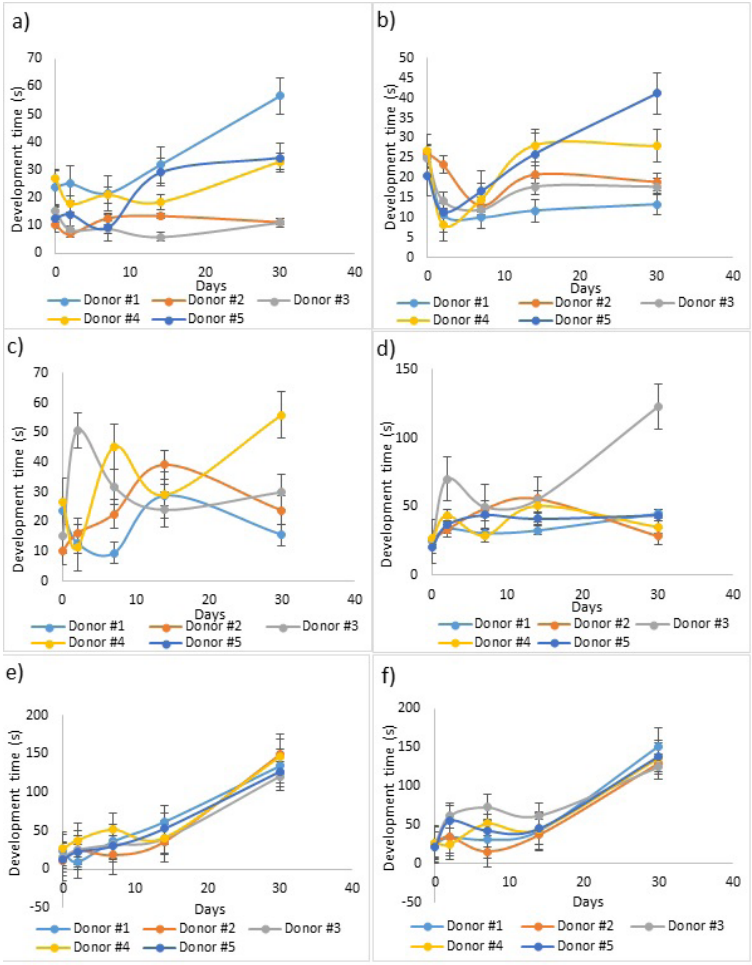

Figure 1

Average development times of aged groomed fingermarks: (a) male donors under dark conditions; (b) female donors under dark conditions; (c) male donors under ambient light conditions; (d) female donors under ambient light conditions; (e) male donors under outdoor conditions; (f) female donors under outdoor conditions.

Groomed Fingermarks on Brass Metal Discs

Ridge detail enhancement (Figure 2) was successful in the vast majority of the samples where the fingermarks were enhanced immediately after deposition.

Examples of fingermarks that were enhanced 2 days after deposition are shown in Figure 3. Because of the short aging period and the high sebaceous content in the deposited impressions, almost all of the fingermarks were enhanced succesfully regardless of the storing conditions.

Fingermarks of identifiable quality were also enhanced 7 days after deposition (Figure 4). At this time interval, no noticeable drop in fingermark enhancement was observed.

Identifiable fingermarks were also obtained after the enhancement was performed 14 and even 30 days after deposition. However, the quality of the enhanced fingermarks was much lower (on average) for the ones that were left outdoors (Figures 5, 6).

As can be seen in Figures 6 and 7, the samples that were left outside show signs of corrosion. However, this is not necessarily a drawback. Wightman et al. [16] demonstrated that a fingermark deposited on a metal surface can cause the surface to become preferentially corroded in the furrows of the fingermark, thus making (sometimes) the latent fingermark visible without any further enhancement.

Figure 2

Groomed fingermark from a male (left) and a female (right) donor were processed immediately after deposition.

Figure 3

Groomed fingermarks from male donor were processed after 2 days under dark conditions (left), 2 days under ambient light (middle), and 2 days outdoors (right).

Figure 4

Groomed fingermarks from a female donor were processed after 7 days under dark conditions (left), 7 days under ambient light (middle), and 7 days outdoors (right).

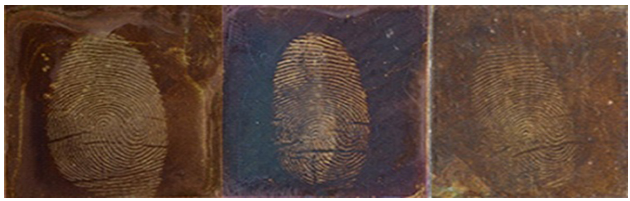

Figure 5

Groomed fingermarks from a female donor were processed after 14 days under dark conditions (left), 14 days under ambient light (middle), and 14 days outdoors (right).

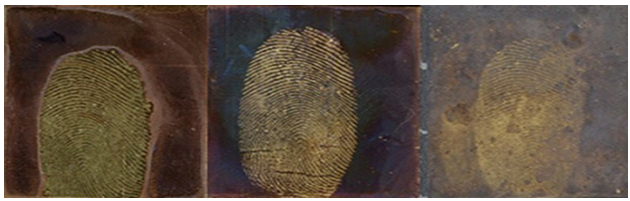

Figure 6

Groomed fingermarks from a male donor were processed after 30 days under dark conditions (left), 30 days under ambient light (middle), and 30 days outdoors (right).

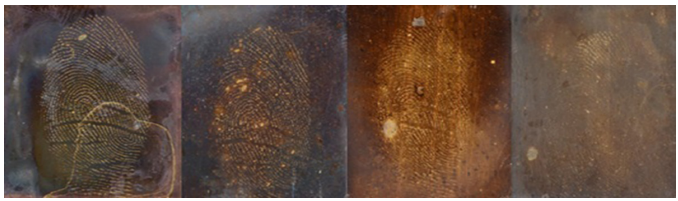

Figure 7

The change in enhancement quality of groomed fingermarks left outdoors from the same donor affected by the time elapsed. From left to right: 2 days old, 7 days old, 14 days old, and 30 days old.

In other instances, the fingermark residue was just removed or degraded with increasing exposure to outside conditions, rendering any successful enhancement highly unlikely (Figure 7).

Ridge Detail Evaluation

An overall depiction of the grading results is provided in Figure 8. As a general observation, darkness, ambient light, and time elapsed under dark and ambient light conditions did not significantly hinder the enhancement of fingermarks. When it came to the samples left outdoors to age, it was difficult to assess what caused the most degradation to the fingermark residue because of the uncontrolled nature of the conditions. We can only speculate that the constant fluctuations of temperature, humidity, wind, and sunlight [17] made the enhancement of fingermarks that had been left more than 14 days to age a difficult task to achieve. It has to be noted that all of the samples were exposed to wet and sunny (UV radiation) conditions at least once before developing them and that exposure to rain may have caused diffusion [16–18] of their components and subsequently lowered the quality of the development by altering the original fingermark ridge detail pattern.

Identifiable fingermarks were also obtained from the brass discs that had been left outdoors to age up to 14 days after deposition. In some cases, identifiable fingermarks were also obtained from samples that had been left to age for 30 days, but for far fewer samples (19 out of 50) compared to the brass discs that had been left under dark (38 out of 50) and ambient light (39 out of 50) conditions. It can be concluded that the proposed time ranges would be the following: 10 to 30 seconds for fingermarks left indoors up to 1 month, 20 to 60 seconds for fingermarks that have been left exposed to outdoor conditions up to 2 weeks, and 100 to 150 seconds for fingermarks that have been left outdoors for 1 month.

Statistical analysis (chi-square tests) after converting the grades of the 400 fingermarks to nominal data (either identifiable or nonidentifiable) showed that the difference between the fingermarks left outside for 30 days and the ones indoors for 30 days was significant (p value ~0.0001). It was also determined that there was no significant difference (p value ~.812) between the samples that were left under dark and ambient light conditions, again for 30 days.

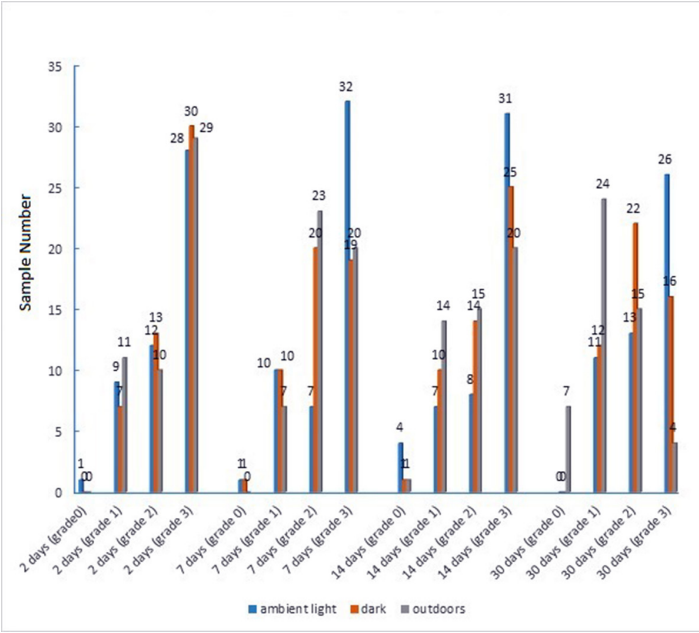

Figure 8

The cumulative grading of groomed fingermarks from all donors in relation to time elapsed since deposition and environmental condition.

An assessment of whether the gender of the donor plays a role in the quality of the enhancement was undertaken. Previous studies [18–20] suggest that fingermark residue from males has a larger amount of oily or greasy components than that of females. Our results confirm this previous finding. From the total number of 300 samples deposited by female donors, 202 were enhanced to an identifiable level. From the total number of 300 samples deposited by male donors, 250 were enhanced to an identifiable level. When processing times exceeded a certain time limit (usually 120 s), that led to unidentifiable fingermark enhancement (possibly because of the lack of greasy or oily compounds). The data was converted from interval data (0, 1, 2, 3) to nominal data (identifiable or nonidentifiable fingermark). A chi-square test indicated that indeed there was a significant difference (p value~0.0001) in the quality of the enhancement between males and females (enhancement with gun blue worked better on fingermarks from male donors).

Natural Fingermarks on Brass Discs

As shown in Figure 9, some of the natural fingermarks on the brass discs were enhanced, and identifiable fingermarks were obtained. However, some of the natural fingermarks were not enhanced to an identifiable grade. Lower quality of enhancement on natural fingermarks compared to the groomed ones is to be expected because of their lower level of fatty components [8, 13, 21–23].

An overall grading of our results on natural fingermarks on brass discs is shown in Table 2. It is clear that the "fresh" condition group gave the best enhancement overall, but this would be expected because they were processed immediately after deposition. The two-week group performed the poorest overall, with only two sets of fingermarks being grade 2 and above.

Condition Subjected	Grade 3	Grade 2	Grade 1	Grade 0
Fresh	7	5	4	0
1 week old (alternating between dark and ambient light)	3	1	11	1
2 weeks old (alternating between dark and ambient light)	2	2	5	7
Light (1 week old)	3	1	6	6
Dark (1 week old)	3	1	7	5
Outdoors (1 week old)	3	2	6	5

Table 2

Fingermark grades of natural fingermarks on brass discs.

Clearly, the number of natural fingermarks enhanced here is not large enough to perform any meaningful statistical analysis. However, it has been shown that gun blue can work on fingermarks with a processing time ranging from 20 to 42 seconds [4] and that fresh natural fingermarks are more likely to be enhanced up to an identifiable level.

Figure 9

Identifiable fresh natural fingermarks from male (middle) and female (left and right) donors.

Fired Cartridge Cases

The most favorable results were acquired from a male donor who deposited groomed fingermarks on cartridges that were fired from the single shot bolt-action rifle (Figures 10, 11). However, only 1 out of 20 was of identifiable quality (grade 2).

A trend was also observed with the enhanced fingermarks on cartridges fired from a single shot bolt-action rifle: the quality of the ridges was much lower near the base (i.e., head) of the cartridge. This might indicate that the gas blowback affects that part of the cartridge when this particular gun is used.

Almost all of the cartridges fired from the single shot bolt-action rifle showed three or four Level 2 characteristics on average, meaning that they can potentially be used for elimination purposes. However, several cases enhanced only minimal ridge detail as shown in Figure 12.

It is notable that some ridge detail from female donors was also enhanced from cartridges that were fired with a .38 S&W revolver. Only 1 out of 20 fingermarks was close to an identifiable grade, but ridge detail was obvious in the majority of them (Figures 13–15). Of all 12 cartridges fired with a .45 Glock, none of them showed any ridge detail enhancement.

It appears that the type of weapon used for firing the cartridges can have a detrimental effect on the enhancement of fingermarks with gun blue. Specifically, it seemed that cartridges fired from the single shot bolt-action rifle and the .38 Smith and Wesson revolver showed overall better quality of enhancement than the ones discharged with the .45 Glock. This finding agrees with that reported by Bentsen et al. [24] However, our sample size was not large enough to draw any rigid conclusions. Gun blue enhanced fingermarks on fired cartridge cases under a controlled environment but had a low success rate when it came to producing identifiable fingermarks (grade 2 and 3). It may be more likely that it could help enhance fingermarks suitable for elimination purposes, which is still information that can aid an investigation.

Figure 10

Fired cartridge case 7.62 mm (single shot bolt-action rifle). Identifiable groomed fingermark from a male donor.

Figure 11

Fired cartridge case 7.62 mm (single shot bolt-action rifle). Groomed fingermark from a male donor.

Figure 12

Fired cartridge case 7.62 mm (single shot bolt-action rifle). Groomed fingermark from a male donor.

Figure 13

Fired cartridge case (.38 S&W revolver). Natural fingermark from a female donor.

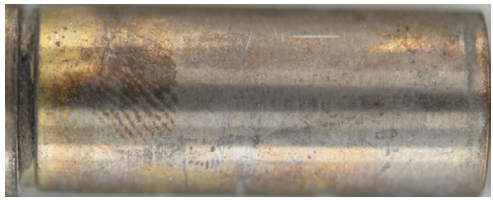

Figure 14

Fired cartridge case (.38 S&W revolver). Natural fingermark from a female donor.

Figure 15

Fired cartridge case (.38 S&W revolver). Groomed fingermark from a female donor.

Conclusions

After a consideration of the results from all donors and from different environmental conditions, certain tendencies of the enhanced groomed fingermarks were observed.

It has been demonstrated that in the majority of cases, groomed fingermarks that had been left to age up to 1 month under dark and ambient light can be successfully enhanced to an identifiable grade (>2) using the gun blue protocol on brass surfaces. However, it must be noted the fingermarks that were used for this part of the study were heavily sebaceous. Most of the time, casework fingermarks may be less resilient to outside conditions or other degrading factors. (In our study, temperature, humidity, air currents, different light level and UV radiation, and substrate corrosion played a part in fingermark degradation.) [25].

It has been shown that there is no standard optimal processing time that can be recommended; however, there are suggested time ranges for this method, depending on the circumstances. The processing time is generally 10 to 30 seconds for fingermarks left indoors up to 1 month, 20 to 60 seconds for fingermarks that have been left outdoors up to 2 weeks, and 100 to 150 seconds for fingermarks that have been left outdoors for 1 month.

This research demonstrates that gun blue can be effective with a variety of donors and that it can be used for groomed fingermarks that have been deposited up to 30 days prior to enhancement even under outdoor conditions.

The potential of developing natural fingermarks on brass discs under different environmental conditions and time intervals was also demonstrated.

The use of gun blue as a stand-alone technique can develop fingermarks (groomed and natural) that are suitable for identification purposes on fired cartridge cases.

Finally, the effects of the firearm used on the success of recovery of fingermarks was considered. A single shot bolt-action rifle and revolver produced the best results. The richest fingermark area was usually around the middle of the cartridge, contradicting the finding of previous research [3], where the fingermark was almost intact near the head of the cartridge.

Further work by the authors is evaluating this process on an increasing range of different firearms and ammunition or cartridge types under varying crime scene conditions, while also including more natural fingermarks.

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